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SIMULATION OF SOME FAULTS IN THREE-PHASE ELECTRIC SYSTEMS USING THE PSCAD-EMTDC PROGRAM

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Abstract:
The main faults and abnormal regimes in the three-phase electric systems are short-circuit and phase interruptions, respectively overcurrents and system's stability loss.
Studying faults and abnormal operation regimes has a special practical importance, because these operation regimes produce malfunctions or even failures of the electric installation, if they are not removed on time.
In this work are analyzed few faults of three-phase electric systems by means of the PSCAD-EMTDC program. Fault analysis with PSCAD can be used for protection relay coordination and for improving the system's performance and reliability.
Keywords:
Three-phase electric systems, Faults, Simulation, Reliability

1. INTRODUCTION

The most frequent faults in electric systems are short-circuiting. Short-circuits' appearance is caused by damaging the insulation or insulation space between phases, or between phase and ground, as result of the loads at rated voltage, or overvoltages that appear in electric installations [1,2].

Short-circuit can be: three-phase (or three-phase-to-earth), phase-to-phase (or phase-to-phase-to-earth) and single-phase (or phase-to-earth fault, produced in the grids with neutral directly grounded).

The three-phase short-circuit is also called as symmetrical fault, because the impedances on phases are equal. This short-circuits, by their consequences, represent the worst fault that might happen into an electric grid. From this reason, the three-phase short-circuit currents are taken as base when selecting the commutation electric devices and verifying them at thermal and electrodynamics stress, verifying the relay protection and automations etc [3-5].

The other short-circuits are called as asymmetrical faults. These are featured by the fact that the phenomena from each phase are produced differently. In these conditions, the phase impedances are unequal and the currents' three-phase system is asymmetrical. Determination of these currents is made by the symmetric components method.

In aerial electric grids, short-circuits are produced, in major cases, by external transitory causes: atmospheric discharges, indirect contact of some phases by foreign bodies etc. After a short time interval from disconnecting the faulty element, the causes might disappear and the insulation in the respective point resume to normal [6].

In these conditions, to prevent a long-term interruption of the consumers' power supply, are provided devices of high speed automatic reclosing (RAR), which connect after a preestablished time the disconnected supply circuits. Earth fault is not an immediate danger, because is not accompanied by big fault currents. However, earth fault of a phase determines the voltage increase of the healthy phases against ground. This increase leads to overstressing the insulation and the danger of its breakdown also in other point from the other phases. Thus, the fault is going to double-earth fault (bi-phase short-circuit to-earth) [7,8].

Beside short-circuits, in the electric systems appear also other faults, such as interruption of a phase. The study of this fault is necessary for designing the parallel lines' protections and to verify if the influence of the negative-sequence components (that appear at a phase interruption) upon generators is within the permissible limits. In case of long-term operation of a line in two phases, is also necessary to verify the influence on the telecommunication lines [4,6].

The main abnormal regimes in electric systems are overcurrents and system's stability loss.

Overcurrents are caused by a short-circuit external to the protected element, or by appearance of some overloads. Overcurrents don't need an immediate disconnection of the protected element, but neither can be admitted on an undetermined period, because they are causing overheatings and, therefore, insulation's wear. Against overcurrents are provided delayed protections [4,6,8].

The system's stability loss can appear due to some short-circuits removed too late, or exceeding the permitted power transported through a line, which causes the dropping-out-of-step of the power plans operating in parallel [8].

Study of faults and abnormal operation regimes in three-phase electric grids has a special practical importance for protection relay coordination. The relay protection should ensure the installation's automatic disconnection when a fault or abnormal operation regime appears, dangerous for the installation. In case of faults and abnormal regimes which don't show an immediate danger, the relay protection is not controlling the installation's disconnection, but warns the appearance of the abnormal regime [9].

Automatic separation of the faulty installation from the rest of the electric system aims three objectives: to prevent the fault's increase, respectively extension of its effects by affecting other installations from the electric system and transforming the fault into a system emergency; to prevent the installation's damage where the fault appears, by rapid interruption of all possibilities to supply the fault; to reestablish a normal operation regime for the rest of the electric system, ensuring the consumer's supply continuity [10].

2. SIMULATION OF SOME FAULTS IN THREE-PHASE ELECTRIC SYSTEMS USING THE PSCAD-EMTDC PROGRAM

Calculation of some faults (short-circuits, phase interruptions, etc.) that appear during the three-phase systems' operation is a complicate procedure, needing to solve some equation systems with a great number of unknown quantities. To simplify the equations and the corresponding equivalent diagrams, can be used the symmetric components' method.

In case of a small circuit with linear elements, determination by normal analysis of the accurate solution is a problem easy to solve. Manual analysis of bigger circuits becomes, however, a very complex problem, being preferable the utilization of a simulation program.

Among the programs used in electric circuits' simulation can be enumerated: PSCAD-EMTDC, SPICE, OrCAD, Multisim.

PSCAD/EMTDC is a general-purpose time domain simulation program for multi-phase power systems and control networks. It is mainly dedicated to the study of transients in power systems. A full library of advanced components allows to precisely modeling interactions between electrical networks and loads in various configurations [11].

PSCAD is ideal for the analysis of electrical transients involving: assymmetrical faults, power line and cables, large non-linear industrial loads, protection relay coordination, arc furnace flicker, distributed power generator, rotating machines, embedded systems [11].

Further, are analyzed few faults of three-phase electric systems by means of the PSCAD-EMTDC program.

2.1 Short-circuit of a phase

Is admitted short-circuit of phase 1 into a circuit where the other two phases have equal impedances, and the voltage system is symmetric (Fig. 1). In simulation, short-circuit was modeled with a null impedance (phase 1 impedance).

Switch K_1 is closed, and after a second it opens. The electric diagram implemented in simulation is presented in Fig. 1. Simulation results are presented in Fig. 2-4.

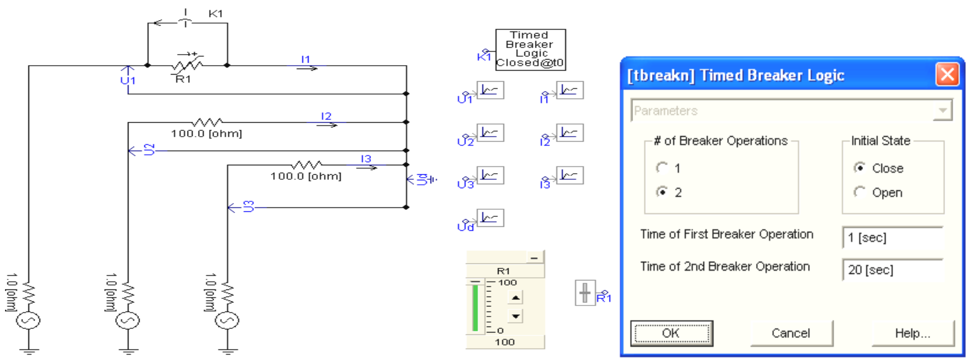

Figure 1. Electric diagram implemented in simulation. Switch K_1 configuration.

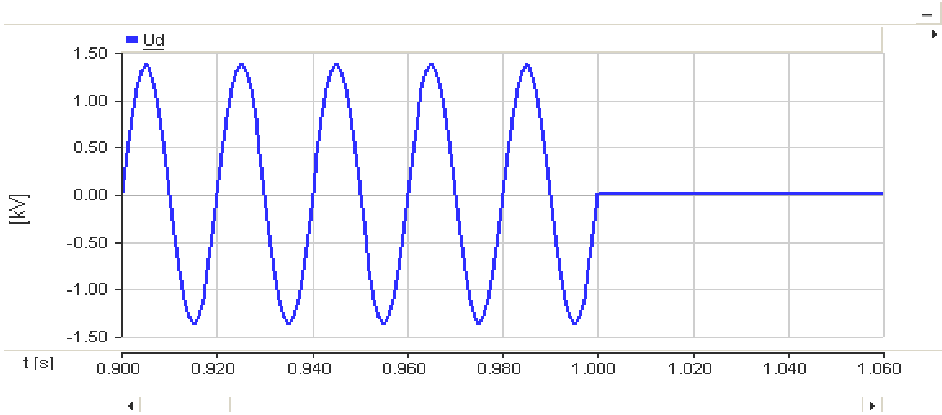

Figure 2. Simulation results. Neutral point displacement voltage.

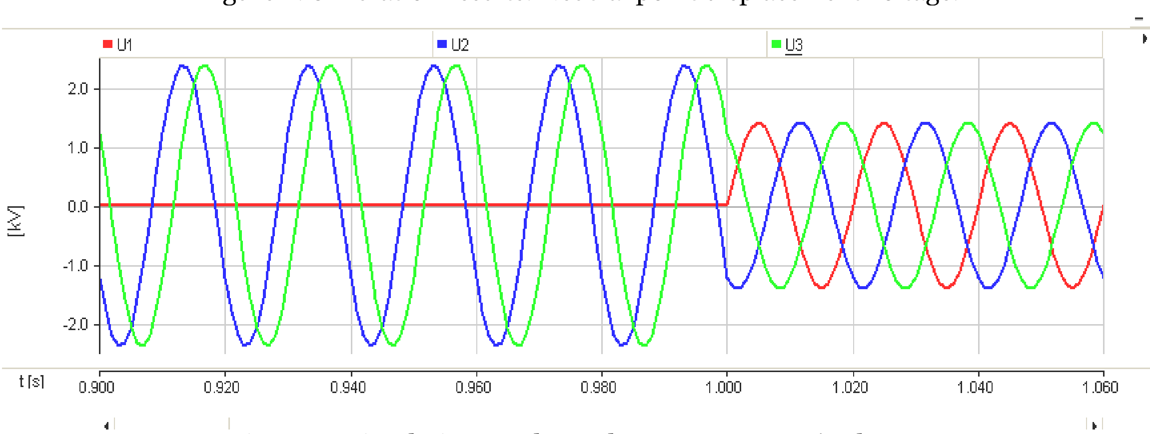

Figure 3. Simulation results. Voltages on receptor's phases.

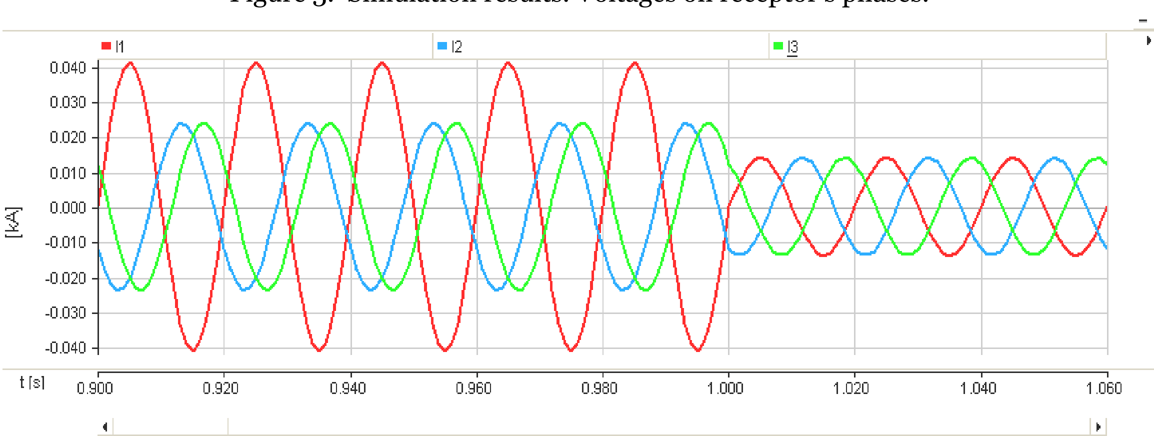

Figure 4. Simulation results. Currents absorbed from the grid.

It is found that voltages on phases 2 and 3 increase by $\sqrt{3}$ times during short-circuit of phase 1. As consequence, currents I_2 and I_3 increase (by $\sqrt{3}$ times) compared to rated currents. This currents are equal (as rms value) and dephased by $\pi/6$ radian. Short-circuit current I_1 increase very much (by 2,8 times) compared to rated current.

After 1 second, switch K_1 opens and the regime becomes symmetric (the receptor is balanced, and the supply voltage system is symmetric).

2.2 Interruption of a phase

Is admitted an interruption of phase 1 into a circuit where the three-phase receptor has the same impedances on phases, and the voltage system is symmetric. Interruptions on phases 1 were modeled with a static and infinite impedance.

Initially the switch K_1 is open and after a second switch K_1 closes. The electric diagram implemented in simulation is presented in Fig. 5. Simulation results are presented in Fig. 6 (voltages on receptor's phases and currents absorbed from the grid).

It is found that the voltage on the interrupted phase increases (by 1,5 times), and the voltages on other phases decrease (by $\sqrt{3}/2$ times) compared to rated voltages.

After 1 second the regime becomes symmetric because switch K_1 closes (the receptor is balanced, and the supply voltage system is symmetric).

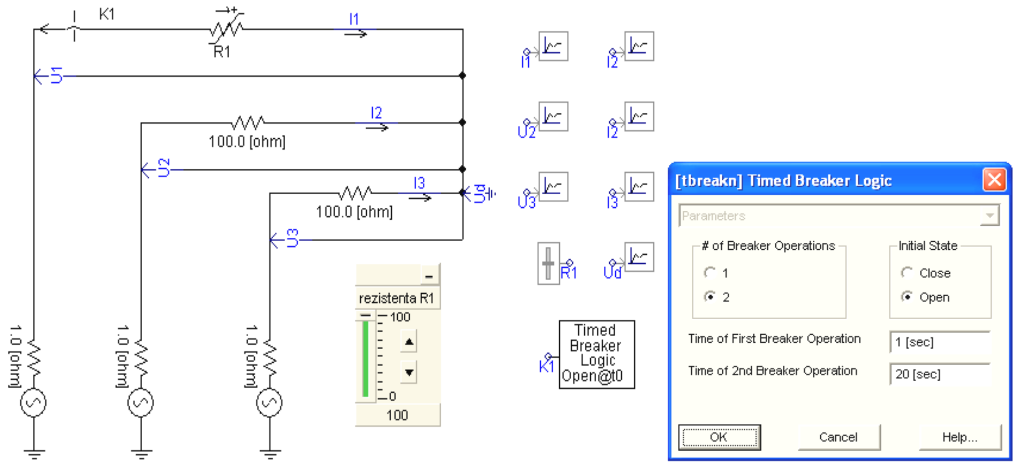

Figure 5. Electric diagram implemented in simulation. Switch K_1 configuration

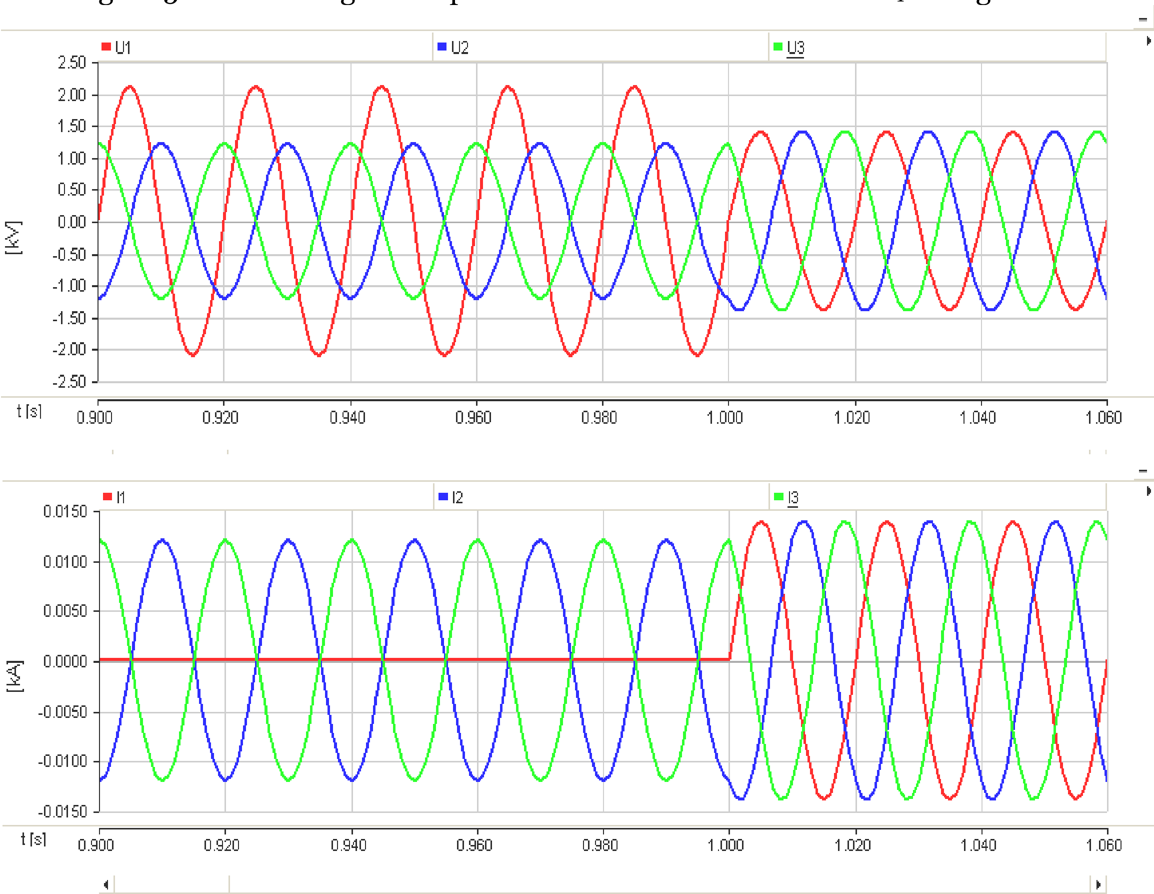

Figure 6. Voltages on receptor's phases and currents absorbed from the grid.

2.3 Short-circuit on phase 1 and interrupting phases 2 and 3

Interruptions on phases 2 and 3 were modeled with static and infinite impedances, and short-circuit on phase 1 was modeled with a null impedance.

During the first two seconds switch K1 is closed, and switches K_2 and K_3 are open. After 2 seconds, switch K_1 opens, and the other switches are closing. The electric diagram implemented in simulation is presented in Fig. 7, and simulation results are presented in Fig. 8, 9.

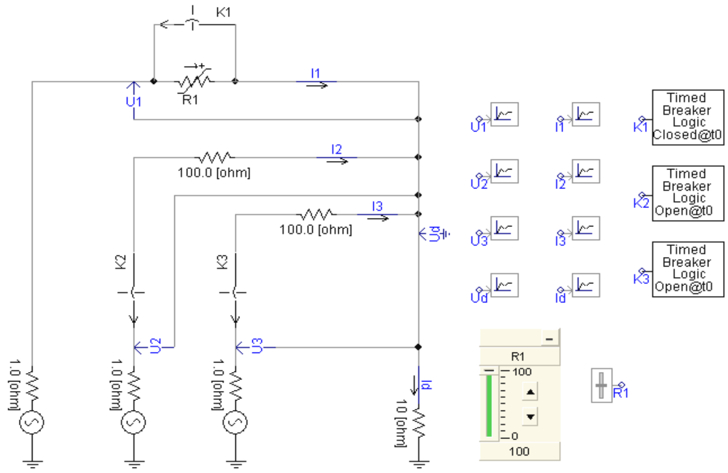

Figure 7. Electric diagram implemented in simulation.

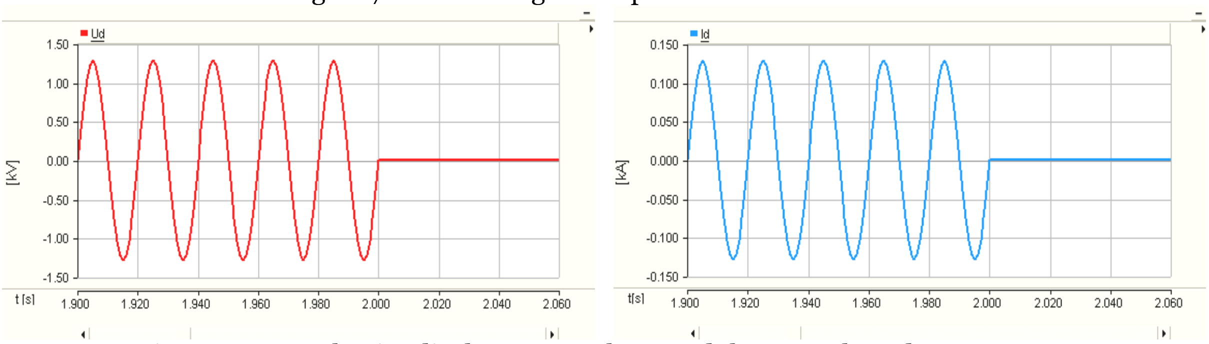

Figure 8. Neutral point displacement voltage and the neutral conductor current.

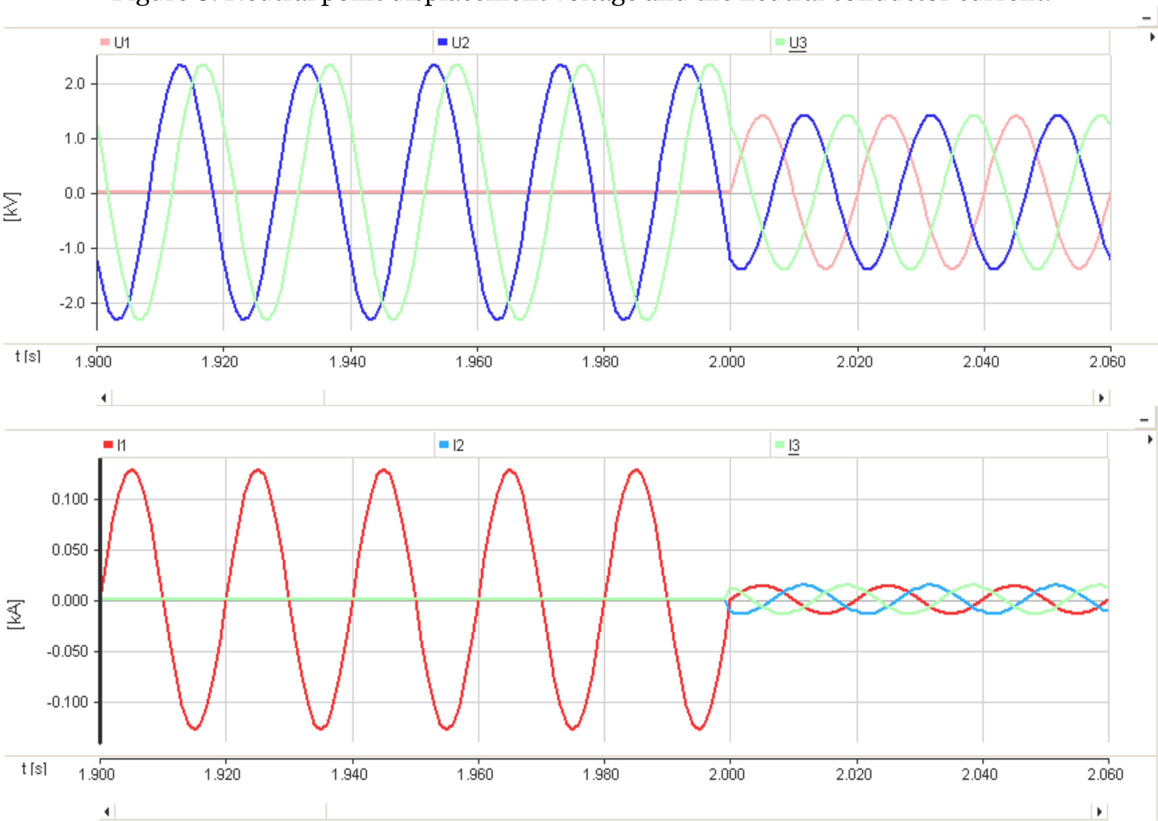

Figure 9. Voltages on receptor's phases and currents absorbed from the grid.

During the fault, the voltages on phases 2 and 3 increase (by $\sqrt{3}$ times). Current I_1 is very high (increases by 21 times compared to rated current), and currents I_2 and I_3 are null. After two seconds, when switch K_1 closes, and switches K_2 and K_3 open, the regime becomes symmetric.

2.4 Short-circuit in two phases and interrupting one phase

Is considered short-circuit in phases 2 and 3 (without earth) and phase 1 interrupted. Short-circuits were modeled with null impedances, and interruption on phase 1 was modeled with a static and infinite impedance.

During the first two seconds, switches K_2 and K_3 are closed, and switch K_1 is open. After this period, switches K_2 and K_3 open, and switch K_1 closes. The electric diagram implemented in simulation is presented in Fig. 10, and simulation results are presented in Fig. 11-13.

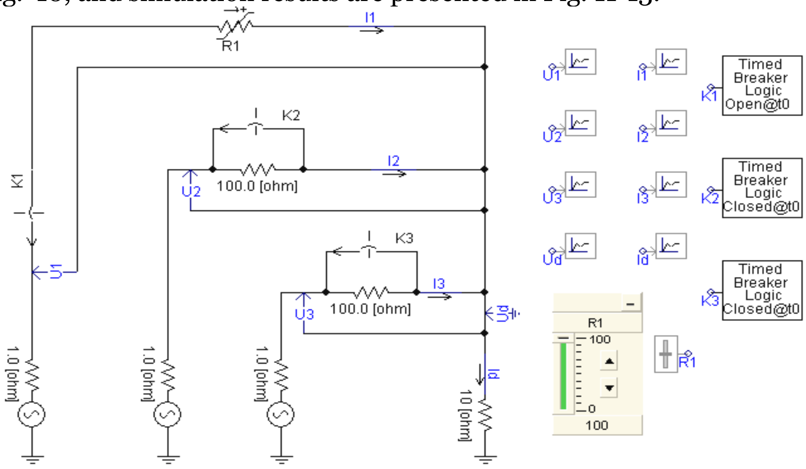

Figure 10. Electric diagram implemented in simulation.

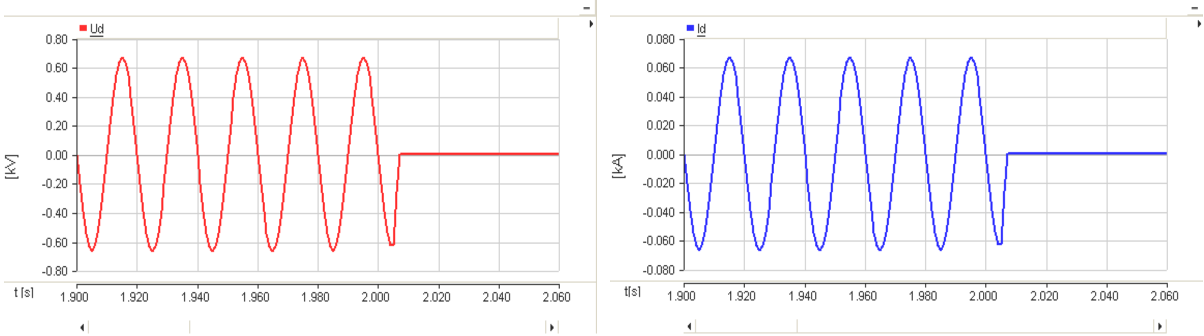

Figure 11. Neutral point displacement voltage and the neutral conductor current.

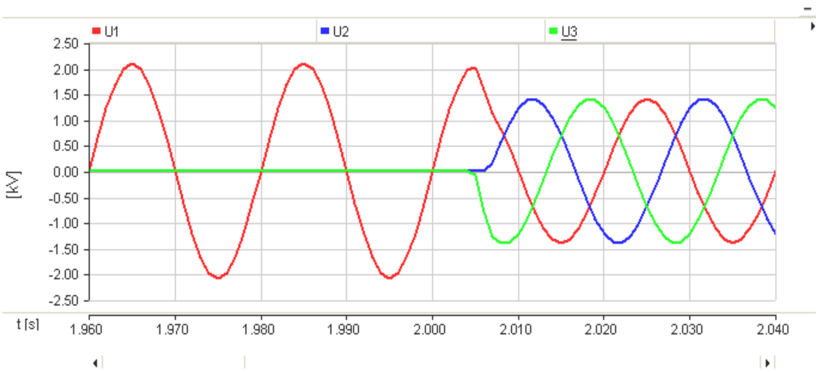

Figure 12. Voltages on receptor's phases.

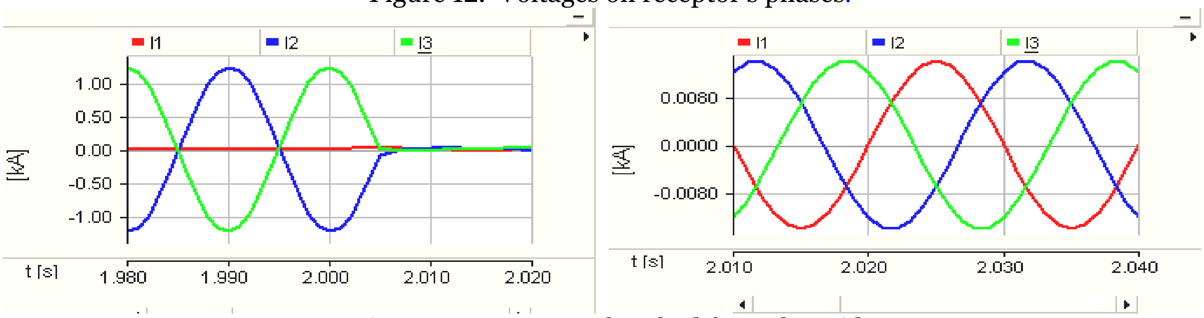

Figure 13. Currents absorbed from the grid.

During the fault the unbalance of system is very pronounced. Phase 1 voltage increases by 1,5 times compared to rated voltage. Current I_1 is null, but currents I_2 and I_3 are very high (increase by 80 times compared to rated currents) and in opposition on phase.

After 2 seconds, switch K_1 closes and switches K_2 and K_3 open. As consequence, the regime becomes symmetric.

3. CONCLUSIONS

Studying faults and abnormal operation regimes in three-phase electric systems has a special practical importance, because these operation regimes produce malfunctions or even failures of the electric installation, if they are not removed on time. Also, the study of faults and abnormal operation regimes are necessary for protection relay coordination.

In this work are analyzed few faults of three-phase electric systems by means of the PSCAD-EMTDC program.

PSCAD is a fast, accurate and easy-to-use simulator, being a very useful tool for analysis of asymmetrical faults.

A full library of advanced components allows to precisely modeling interactions between electrical networks and loads in various configurations. Users can easily interact with the components during the simulation because of the variety of control tools. The solution meters and the plotting traces are also visible and available during the simulation. Signals can be analyzed in real time.

The time steps interpolation technique combines accuracy and quickness; it allows the simulation to precisely represent the commutations of breakers and switches in the electrical model, for any model's size, up to extremely large models.

Fault analysis with PSCAD can be use for improving the system's performance and reliability.

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